Ground Magnetic Attributes for Subsurface Structural Analysis of Foundation Beds in a Sedimentary Terrain in South-western Nigeria: OSUSTECH Permanent Site as a Case Study

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Abstract— The structural failure such as subsidence, collapse and cracking of the walls of buildings in Nigeria has posed a threat or a significant potential hazard to the community in the affected areas. These hazards include gross loss of valuable lives and properties that always accompany such structural failure. Therefore there is need for subsurface structural analysis. The Stop-And-Go method was used for the acquisition of the data. This method is good for subsurface investigation at depths below 30 metres (100 feet). Data for this study were taken at a 10 metres station spacing which is about half that of the expected depth of target. The method requires the technique of measuring total field components at discrete points along the traverses distributed regularly throughout the survey area of interest. The raw data were processed to remove diurnal variations from the total field data measured from the base station. Interpretation of the ground magnetic data revealed that the study area comprises zones underlain with thin to thick overburden. In all the profiles, the regions A and B are associated with the high magnetic values except in the profile 4 in which only region E is associated with high magnetic values. Thus, the region E in the profile 4; the regions A and B in the profiles 1, 2, 3 and 5 are competent zones for the sitting of structures. It can be deduced that the regions of high magnetic susceptibility and high resistivity are competent zones for construction of high rise buildings and other engineering structures. While the regions of low magnetic susceptibility and low resistivity could pose problem of subsidence of the buildings around the region.

Keywords— ground magnetic; subsidence; stop and go; structural analysis; diurnal variation

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1. Introduction

The geophysical mapping of bedrock configuration is highly significant and a key means of reducing alarming rate of structural failure such as roads, buildings, dam and bridges in Nigeria. The structural failure in Nigeria has posed a threat or a significant potential hazard to the community in the affected areas. These hazards include gross loss of valuable lives and properties that always accompany the structural failure. Therefore there is need for subsurface structural analysis to avert these hazards. In civil engineering, it helps to determine the appropriate and safest depth to place the foundation of our buildings (Alagbe et al., 2013).

Meaningful evaluations of subsurface fracture distribution in urban or sub-urban areas are usually carried out using surface geophysics such as ground magnetic survey method (Sunmonu et al., 2013). The ground magnetic method is quite appropriate in the investigation of subsurface structure on the basis of the anomalies in the earth's magnetic field resulting from the magnetic properties of the underlying rocks. Magnetic method has been previously used for subsurface analysis of foundation beds, locate rocks or minerals having unusual magnetic properties which reveal themselves as anomalies in the intensity of the earth's magnetic field. It has been used extensively in basement mapping and subsurface geological structures such as rock contacts, rock boundaries, fractures and faulted zones (Adagunodo and Sunmonu, 2012; Sunmonu et al., 2012).

Ground magnetic was used to investigate the cause of the subsidence at an Abandoned Local Government Secretariat, Ogbomoso, South-western Nigeria with a view to determining whether the sinking and cracks in the plasterworks experienced at the Eastern side of the study area is due to subsurface features or insufficient use of building materials (Adagunodo et al., 2013).Generally, most of the building failures happening today are people's ignorance about subsurface features (Adagunodo et al., 2015). Therefore, it is necessary to carry out this geophysical survey, which will reveal the geomagnetic pattern in the study area to have a prior knowledge of the impending danger associated with incompetent areas where engineering structures have been erected. In this research, the magnetic method was used because it is fast, it covers a large area within a short period of time and has ability to delineate the geological structure and basement relief.

2. Location and Geology of the Study Area

The study area is part of the permanent site of the Ondo State University of Science and Technology (OSUSTECH), Okitipupa. This area is the proposed Faculty of Engineering building site at OSUSTECH Okitipupa. The study site geographically lies between longitude 4°3' E to 6°00' E and latitude 5°42' N to 8°15' N.

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Politically, OSUSTECH, Okitipupa is in the Southern Senatorial district of Ondo State, in south-western Nigeria (Figure 1). Okitipupa is a coastal area and is at the contact between the Niger Delta sedimentary basin and the Dahomey basin in Nigeria (Figure 2), which stretches from this point in Nigeria through republic of Benin, Togo and terminates at Ghana, the second largest bitumen deposit in the world is located at Agbabu area in Okitipupa area, Ondo State, Nigeria. The land rises from the coastal part of Ilaje/Ese Odo (less than 15m above sea level) in the South to the rugged hills of northern eastern portion in Akoko area. Sand ridges, lagoon and swampy flats of sedimentary terrain characterize the area. It belongs to the sedimentary terrain of Nigeria (Omosuyi, 2001).

Fig. 1: Map of Ondo State showing the study area

Ozegin (2012) described the lithologies within the Dahomey as coastal plain sand of the Benin formation. The sands are relatively well sorted and non-cemented and the sediments were deposited during the late Tertiary-Early Quaternary period (Ozegin et al, 2012). Okitipupa area has three distinct type of soil namely Okitipupa series, Omotosho series and Ode Erinje series. Okitipupa series occupy 52% or 41,623 hectares of the entire land areas and are thus the most extensive soil within the local government area. The soils are associated with nearly plains of 0-4% slopes of elevation of 40-60m above sea level and are developed on recent to tertiary sediments termed coastal plain sands or cretaceous Abeokuta formation (Obasi, 2013).

The Omotosho soil series constitutes 21.64% or 17,318 hectares of the land area of the local government and are associated with strongly undulating topography of 8-12% slopes at high elevations of 60-105m above sea level. The soils are restricted to the northern tip of the local government area within the Omotosho area and are derived from basement complex rocks composed mainly of granite-gneiss, mica-schist and feldspathic rocks.

The Ode Erinje Fadama Soil series occupy 26.36% or 21,099 hectares of the land area on nearly level plains of 0-1% at very low elevations of 10-20m above mean sea level. They are underlain by coastal plain sands and are seasonally waterlogged, strongly gleyed (Esu et al., 2014). Hydrogeologically, Omosuyi (2001) concluded a Southward transition from basement to sedimentary rocksthrough groundwater studies using electrical resistivity survey in Okitipupa local government. Apart from Oluwa river that runs through the state other sources of surface water also includes river Akeun, Omiju, Omiyewa and Chen flow through sedimentary rocks into the coastal lagoons. These rivers also support fishing and irrigation.

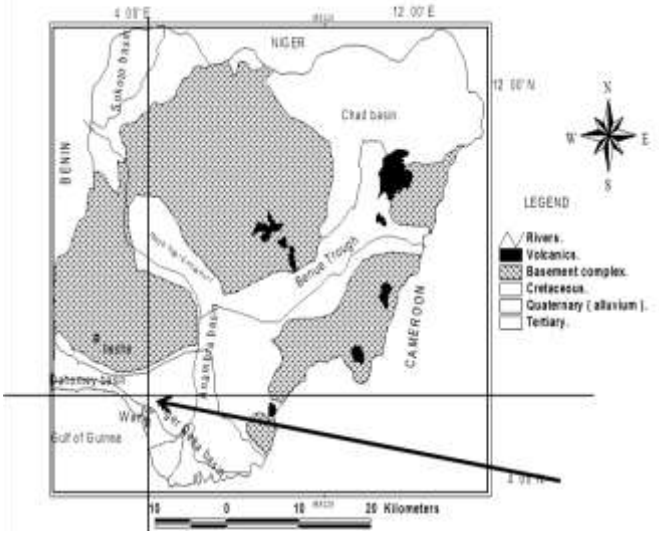

Fig. 2: Geologic map of Nigeria showing basement complex and sedimentary

3. METHODOLOGY

The Stop-And-Go method was used for the acquisition of the data. This method is good for subsurface investigation at depths below 30 metres (100 feet). Data for this survey was taken typically at a 10 metres station spacing which is about half that of the expected depth of target. The method requires the technique of measuring total field components at discrete points along the traverses distributed regularly throughout the survey area of interest.
The instrument used for the ground magnetic survey is the GEM system Proton Precession magnetometer, model GSM-19T which produces an absolute and relatively high resolution of the field and displays measurement in digital lighted readout. The instrument was used because of its availability, high accuracy and easy operation. The sensor was mounted horizontally, so that the cylindrical axis is perpendicular to the staff. In this configuration, the sensor has a north arrow on its side which was always directed towards the geographic north when taking a measurement. Garmin etrex legend global positioning system (GPS) was used for taking the longitude and latitude of the survey area and elevations of certain points.

A total of five (5) traverses were established for the survey and the results were presented as ground magnetic profiles of varying intensities. The traverse length ranges from 100m to 180m with inter station spacing of 10m. Two of the traverses were in the North-South direction while the other three were in the East-West direction. To make accurate magnetic maps, temporal changes (diurnal variation) in the earth's field during the period of survey were monitored by selecting a base station, where the magnetic intensities are being measured at a stationary point.

The raw data were processed to remove diurnal variations from the total field data measured from the base station. After these corrections were done, the data were presented as magnetic profiles by plotting the magnetic susceptibility values against station separations for each traverses.

These magnetic susceptibility values were correlated with the electrical resistivity values obtained along the same profiles by Salami (2013). The iso-resistivity map that relates the magnetic susceptibility and electrical resistivity of the subsurface lithology was generated.

4. Results and Discussion

4.1 Qualitative Interpretation of Magnetic Profiles

Profile 1

The profile covers a total length of 160m and trends in the North to South direction (figure 3).This profile falls beside the parking lot of the faculty, behind the science building. The profile generally shows high (A and B) and low magnetic values (C and D) depicting magnetic heterogeneity of the area. The high magnetic at A and B are suspected to be due to near surface magnetic minerals such as crystalline rocks (igneous or metamorphic rocks). The region can host high building as the thin overburden and presence of basement rock could serve as a strong foundation for them. The low magnetic at C and D are suspected to be fault, fracture, or crack and this is further confirmed by the high conductivity on the iso-resistivity map. These areas may be of hydro-geological importance.

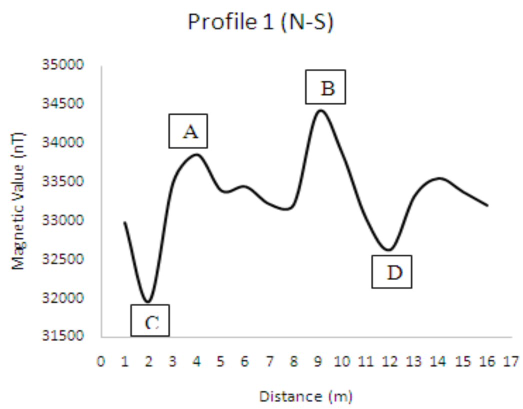

Fig. 3: Plot showing the magnetic value along Profile 1

Profile 2

The profile is a total of 140m long and trends in the East to West direction (figure 4). The profile is at the back of the Information and Communications technology (ICT) block which is at the South-western side of the study area. The profile shows high magnetic values at A and B and low magnetic from C to D. The high magnetic areas are suspected to be near surface magnetic minerals such as crystalline rocks (igneous or metamorphic). These areas are regarded as competent zones for building structures. The zone C to D is a ultra-low magnetic material while E is suspected to be a near surface fault or contact and will be poor for geotechnical viability.

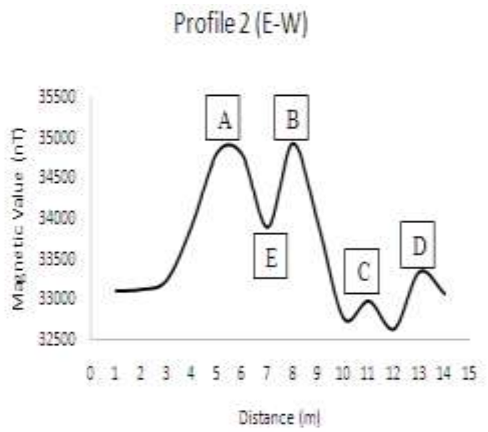

Fig. 4: Plot showing the magnetic value along Profile 2

Profile 3

The profile 3 extends to a total of 180m length, and trends north to south direction (Figure 5). The magnetic profile shows a trend of high magnetic value descending to a magnetic low linearly from B to C. This geologic structure is suspected to be an inclined vertical dyke of magnetic mineral, dipping along the profile length. This might be good for hydrogeological purposes. The regions from A and B are associated with high magnetic values and is indicative of subsurface structures that are good for engineering purpose. This profile is on the road that links the faculty to the school farm. The possibility of road failure is suspected in the regions B and C. These zones are poor for erection of engineering structures due to thick clay sediments embedded in the subsurface and might need excavation before construction. Zone D embedded high magnetic body.

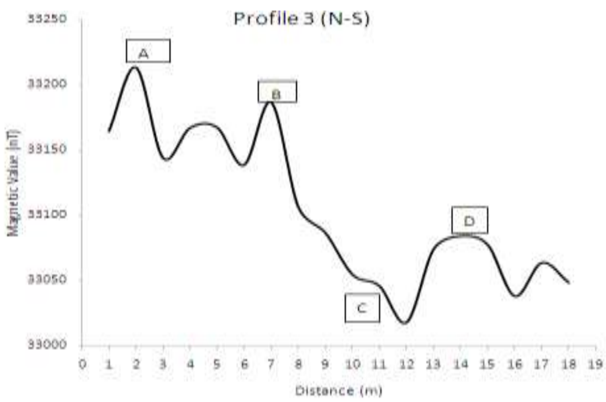

Fig. 5: Plot showing the magnetic value along Profile 3

Profile 4

This profile covers 140m length and trends in the east to west direction (Figure 6). The traverse is behind the Student Affairs Block, as at the time of survey. Zones of inflection at A, B, C and D are indicative of contact between different rocks of different susceptibility. Zone E is indicative of high magnetic material which may be good for engineering purposes.

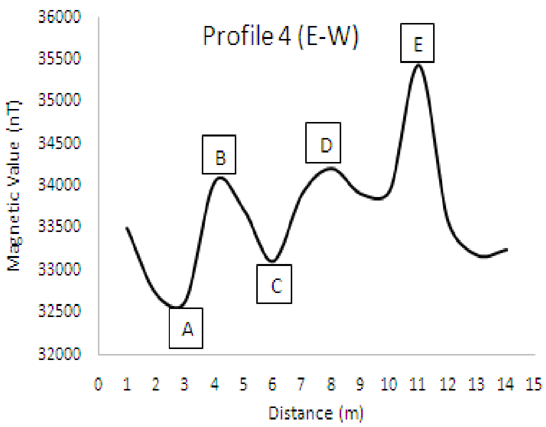

Fig. 6: Plot showing the magnetic value along Profile 4

Profile 5

The profile is 100m in length and trends in the East to West direction (Figure 7). There are high magnetic values at A and B. The low magnetic at C indicate a fractured zone which might be considered for hydrological purposes. This profile stretches from the parking lot to between the Student Affairs Block and the University Auditorium. Zones A and B will be useful for engineering purposes.

Fig. 7. Plot showing the magnetic value along Profile 5

4.2 Qualitative Interpretation of Magnetic Maps

The total intensity map (Figure 8) shows the magnetic amplitude and acute variation in the magnetic intensity, indicating variations in either lithology or basement topography. These variations can be classified into distinctive zones. There are three different zones based on the magnetic variations, which are possibly related to the zones of structural variations based on the geologic investigations. The highest magnetic intensity values are located at the North-North Eastern (NNE) and South-South Western (SSW) parts of the study area. It may represent very shallow basement and are indicative of competent zones that are very viable for engineering purposes. It seems that there are considerable variations in the subsurface magnetic sources. From the North towards the extreme North-Western part of the area is characterized by intermediate magnetic anomaly amplitude, indicating that there are relatively deep and/or non-magnetized source and/or basement dipping North-West. This is followed by a very low magnetic anomaly at the extreme North-Eastern portion of the area, and some localized low magnetic values (blue colour) across the map.

The Iso-Resistivity Map shown in Figure 9, relates the magnetic susceptibility and electrical resistivity of the subsurface lithology. The regions with high magnetic susceptibility and extremely low electrical resistivity (high conductivity) indicate that thick clay sediments are embedded in the subsurface. This may pose problem of subsidence to the buildings around these regions, due to the swelling nature of clay. It is advised that deep excavation be made in the regions before structures could be constructed. The regions of low magnetic and corresponding low resistivity indicate probable faulted zone or porous formation with water content. These regions are not safe for erection of engineering structures.

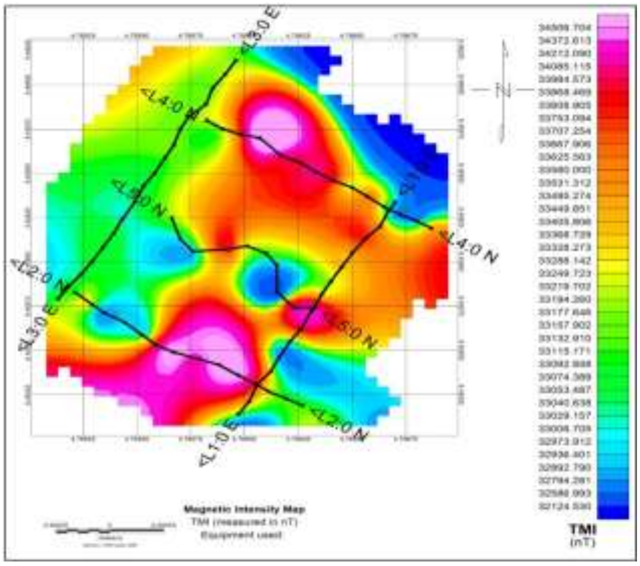

Fig. 8. Total Intensity Ground Magnetic map generated for the study area: diurnal corrected.

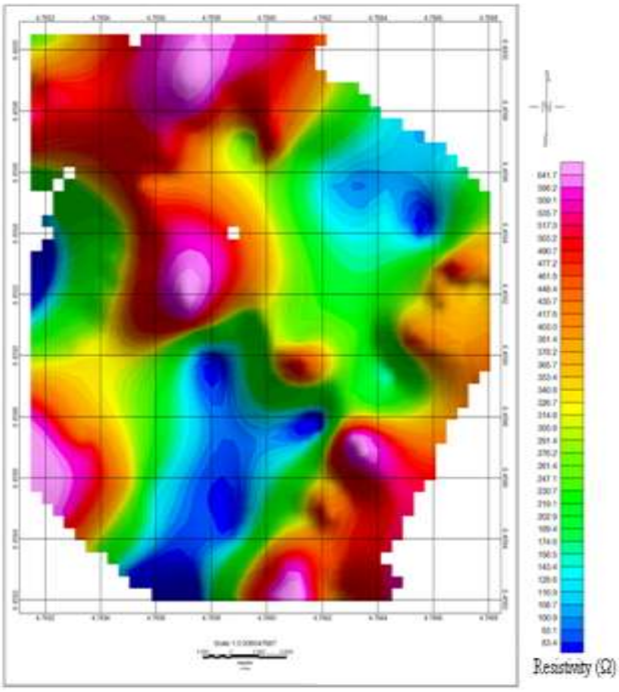

Fig. 9.Isoresistivity map generated for the study area

5. Conclusion

In all the profiles, the regions A and B are associated with the high magnetic values except in the profile 4 in which only region E is associated with high magnetic values. Thus, the region E in the profile 4; the regions A and B in the profiles 1, 2, 3 and 5 are competent zones for the sitting of structures.

The regions of high magnetic susceptibility and high resistivity are competent zones for construction of high rise buildings and other engineering structures. The regions of low magnetic susceptibility and low resistivity could pose problem of subsidence of the buildings around the region.

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